5-1973

Effects of Manipulating FR Size and Reinforcement Magnitude in Multiple FR Schedules

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EFFECTS OF MANIPULATING FR SIZE AND REINFORCEMENT MAGNITUDE IN MULTIPLE FR SCHEDULES

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Psychology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1973

ACKNOWLEDGEMENTS

I would like to sincerely thank Dr. Carl Cheney for his assistance, encouragement, and for the effort that he too has contributed to this research effort. I would also like to thank Dr. J. Grayson Osborne for the support he has generously given me these last two years.

Dean P. Inman

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Effects of Manipulating FR Size and Reinforcement Magnitude in Multiple FR Schedules

by

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Utah State University, 1973

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Animals performing on simple fixed-ratio (FR) schedules typically pause after reinforcement delivery. The present study demonstrated systematic control of pause length in multiple fixed ratio schedules by manipulating FR size and reinforcement magnitude. In Experiment I, two adult male rabbits were stabilized on an alternating, two component, multiple FR 10 FR 10 schedule. Different colored lights were correlated with both FR components. Stability was determined and mean pause lengths were calculated as one FR component was increased in size until the schedule was FR 10 FR 50. Pausing was longer before the large FR component and was positively correlated with increases in FR size. Schedule and stimulus control were demonstrated by randomizing the order of FR presentations and by reversing the colored lights previously correlated with either the small or large FR components. Existing pause differentials were not disrupted under the light reversal or random conditions.

In Experiment II, the same rabbits were stabilized at mult FR 10 FR 30 with ½ cc of water delivered after each component. In

subsequent conditions the magnitude of reinforcement (cc's of water) delivered at the completion of the large FR component, was systematically shifted from 4 cc, to 3 cc, 2 cc, 1 cc and finally back to ½ cc. Pausing before the large FR was found to be inversely related to the magnitude of reinforcement delivered in that component.

Clearly the animals in this experiment discriminated upcoming schedule conditions and paused relative to FR size and reinforcement magnitude. Hence, it is proper to point out that the term "post-reinforcement pause" is a misnomer since it incorrectly implies a functional relation between pause length and prior schedule conditions.

(52 pages)

INTRODUCTION

In simple fixed-ratio (FR) schedules, reinforcement is delivered contingent upon an animal completing a predetermined number of responses. A response pattern described as either "bimodal" (Ferster and Skinner, 1957), or "break and run" (Cumming and Schoenfeld, 1958), is characteristic of animals exposed to FR contingencies; i.e., animals typically respond at a high rate until reinforcement, pause, and then resume responding at the original high rate until subsequent reinforcement. The pause between response bursts has been described as a "post-reinforcement pause" (Felton and Lyon, 1966) inasmuch as it immediately and consistently follows reinforcement delivery. The present research investigated some factors that determine the length of the post-reinforcement pause (PRP) in multiple fixed-ratio schedules.

There are various complex schedules that employ combinations of simple FR components. One such schedule is a multiple fixed-ratio schedule where every FR component is associated with its own stimulus condition. For example, a multiple fixed-ratio 20, fixed ratio 30 (mult FR 20 FR 30) contains two independent FR components (an FR 20 and an FR 30) and each is associated with its own discriminative stimulus. Individual FR components may be presented in alternation, in a predetermined series, or in some randomized sequence.

This paper reports findings that 1) systematically replicate previous findings relating PRP to the size of the fixed ratio, 2) extend current data so as to more clearly delineate variables

functionally related to PRP; i.e., the effects of reinforcement magnitude, and 3) discuss the improper implications that the term "post-reinforcement pause" carries with it. Data reported here were collected using multiple fixed-ratio schedules with FR components presented randomly and in simple alternation.

REVIEW OF LITERATURE

Performance on fixed-ratio schedules has been described as "bimodal" in that animals either respond at a very high rate, or not at all (Ferster and Skinner, 1957; Barofsky and Hurwitz, 1968; Powell, 1970). Periods of zero responding generally follow reinforcement delivery and consequently have been referred to as "post-reinforcement pauses" (Felton and Lyon, 1966). The length of time an animal pauses after reinforcement has proven sensitive to several types of experimental manipulation and appears functionally related to a number of independent variables. For example, many investigators have shown that post-reinforcement pause (PRP) is functionally related to the size of the fixed ratio.

One of the earliest examinations of post-reinforcement pause was conducted by Skinner (1938). It was the purpose of the study to examine the effect that increasing the size of the fixed ratio would have upon the time animals paused after reinforcement. Skinner found that the two variables were positively correlated. That is, as FR size was increased from FR 48, to FR 96 and finally to FR 192, the time that elapsed between reinforcement and subsequent responding (PRP) increased from 73 sec, to 95 sec, and 120 sec respectively.

Kaplan (1956) and Winograd (1965) have investigated post-reinforcement pause using simple fixed-ratio schedules and escape paradigms. Kaplan exposed rats to a very bright light and then measured latency to the first escape response, which produced a

dark or time-out period. The response requirement was then varied from FR 1 (CRF) to FR 30. Results showed that PRP increased exponentially as the size of the fixed ratio was increased. These results have been systematically replicated by Winograd (1965). In this experiment rats were exposed to a shock delivered through a grid floor, given sixteen trials at FR 1 (CRF) and then subsequently tested at FR 5, FR 10, and FR 20. At each schedule level the shock generator was held constant at 0.8 ma (for two animals) or 0.6 ma (for a third animal). Winograd reported that mean latencies between shock onset and the first escape response (PRP), increased as the response requirement was raised. This is not to say that time-out from aversive conditions (negative reinforcement) is analogous to positive reinforcement, but the data from Kaplan (1956) and Winograd (1965) do agree with Skinner's (1938) in that they show pausing after reinforcement does vary as a function of increasing the size of the fixed ratio.

Felton and Lyon (1966), investigated PRP by manipulating the size of simple fixed-ratio schedules. Pigeons key pecked on FR 50 until responding became stable at which time the schedule was shifted to FR 75, then to FR 100, and finally to FR 150. These investigators also reported a positive correlation between changes in FR size and PRP. Powell (1968) similarly investigated PRP, but increased FR size in smaller steps, so as to avoid the retraining that is required after making large changes in FR size. Pigeons were stabilized at FR 10 then shifted in steps to FR 15, 20, 30, 40, 50, 60, 75, 90, 105, 120, 140, 160, then back to FR

120, 90, 60, 40, 20, and finally to FR 10. Again, it was found that post-reinforcement pause increased relative to the increases made in FR size.

It should be pointed out that although the above data show a positive correlation between FR size and PRP, they fail to indicate whether the changes in pause after reinforcement are controlled by manipulating the size of the preceding or the up-coming ratio, since, in simple FR schedules, preceding and up-coming ratio sizes are identical. Schuster (1959), using multiple fixed-ratio schedules attempted to clarify the effects that changes in schedule size have upon PRP. In his first experiment, he exposed pigeons to an alternating mult FR 20 FR 20 until performance became stable prior to exposing them to each of three other schedules: mult FR 10 FR 20, mult FR 40 FR 20, and mult FR 80 FR 20. On each schedule, PRPs were calculated for both FR components. Schuster found that as one FR component was increased, holding the other constant at FR 20, pausing prior to the latter significantly shortened and pausing prior to the former increased relative to the FR increase. Similarly, as the one ratio was shortened to FR 10 with the other held constant at FR 20, pausing prior to the latter increased, while pausing prior to the FR 10 significantly decreased. The changes in pausing before the altered FRs appear to be functionally related to the size of up-coming ratio. But Schuster describes the changes in FR 20 pausing as "contrast effects" in that they shifted purely as a function of manipulating the size of the alternate FR components.

In Experiment II, Schuster exposed the same pigeons to mult FR 80 FR 20, mult FR 80 FR 40, and mult FR 80 FR 10. Latency shifts were similar to those reported in Experiment I, except that the contrast effects at these higher values did not endure longer than 14 days. That is, there was a temporary increase in pausing before the FR 80 as a function of decreasing pause time in the shorter FRs. Schuster suggests that these results show PRP is primarily controlled by the size of the up-coming schedule requirement, but also that pausing is affected (at least temporarily) by the relative size of the alternate ratio.

Disregarding for the moment the contrast effects reported by Schuster (1959), the above data indicate a seemingly ubiquitous relationship between post-reinforcement pause and size of the up-coming FR requirement. Indeed many investigators have suggested that PRP is a function of the size of the up-coming fixed ratio (Davidson and Over, 1966; Crossman, 1968; Powell, 1970). Though its effect on PRP is well documented, FR size cannot be regarded as the sole determinant of pause length for there is considerable evidence showing other variables are also functionally related to PRP. For example, Azrin (1959) reported a positive correlation between PRP and shock intensity. For this experiment, six pigeons were exposed to simple FR schedules ranging from FR 10 to FR 50. As each bird stabilized at his particular schedule level, a punishment contingency was added; i.e., a 0.05 sec shock was delivered by means of pubis bone electrodes after each response. Over a period of four months, shock intensity was increased from 1 to 3,

7, 10, 20, 40, 60, 80, 100, and finally to 120 volts. At each shock intensity, local FR rate remained virtually unchanged but pausing between reinforcement and subsequent responding (PRP) increased relative to increases in the intensity of response-contingent shock. These data are interesting in that FR size was held constant throughout the experiment, and yet PRP remained sensitive to changes in shock intensity.

Of similar interest, are experiments by Weiner (1964) and Azzi, Fix, Keller, and Silva (1964). These studies examined the effects that response cost and delay of reinforcement have upon FR performance respectively. Weiner exposed four adult humans to an FR 50, and reinforced them by adding 100 points to a point total. In stage one, a simple FR 50 was used with no response-cost condition. Stage two added a five-second-response-cost condition where one point was subtracted for every response emitted within five seconds after reinforcement. Stage three added a third condition where the one-point-cost condition was in effect continuously, i.e., after every response. Stage four was similar to stage two except that a 5 sec, two-point-cost condition was used, and stage five employed the two-point-cost condition continuously. The results showed that post-reinforcement pause occurred only in response-cost conditions and that the length of the PRP increased as a function of the duration of cost conditions but not as a function of the amount of cost per response.

Azzi, et al. have reported a relation between post-reinforcement pause and delay of reinforcement. Three male rats were

exposed to FR 1 (CRF) and allowed to earn 50 reinforcers with no delay between the response and reinforcement. Then subject's were subjected to delays of 1, 3, 5, 7.5, and 10 sec successively by imposing a black-out period between each response and reinforcement. At each delay value, subject's were given 150 reinforcements. Results indicated proportional increases in PRP with each increase in reinforcement delay.

Of particular relevance here is the fact that PRP remains sensitive to experimental manipulation with FR size held constant. This then extends the previously described relationship between simple FR size and PRP. If up-coming conditions include a large work requirement, delayed reinforcement, response-cost conditions, response-contingent shock, or presumably any event generally regarded as "aversive", then the time an animal pauses before encountering those conditions increases accordingly. Realizing this, it is not unreasonable to expect that PRP should shorten if up-coming events are made relatively more reinforcing.

Two studies support the above conjecture. Mintz, Mourer, and Weinburg (1966), using pigeons with FR size held constant at FR 85 or FR 125, varied the number of consecutively reinforced responses that followed each sequence of responding. That is, FR completion was reinforced with one, two, three, or four consecutively reinforced responses (technically, a mixed FR CRF). The results showed an inverse relation between PRP and the number of successively reinforced responses. As total amount of reinforcement for FR completion increased, pausing prior to that FR

decreased accordingly. Similarly, Powell (1969) examined PRP as a function of duration of food presentation (allegedly the same as reinforcement magnitude). Pigeons were tested with various FR requirements and reinforced with 2.5 sec access to a grain hopper every other day and 4.0 sec on alternate days. Results showed that at each FR size, pausing was consistently shorter when the longer reinforcement duration was in effect, suggesting that manipulation of either independent variable (FR size or food-access time) would effectively control PRP.

That PRP becomes longer when increases are made in such variables as FR size, delay of reinforcement, etc., is at present beyond suspect. But, that PRP decreases as a function of increasing reinforcement magnitude, remains to be adequately demonstrated. Regretably, there are some technical problems with Powell (1969) as well as with Mintz et al. (1966) regarding their procedures for increasing reinforcement magnitude that preclude firm conclusions regarding its effects on PRP. Specifically, both of these studies purport to have increased magnitude of reinforcement by having increased total access time to a grain hopper. There are several reasons, however, why this procedure may not proportionally increase the amount of food that each animal consumes.

First, pigeon feed (used as reinforcement) generally consists of 50% kafer, 40% vetch, and 10% hemp (Ferster and Skinner, 1957, p. 29). Therefore, it is possible that pigeons, which have a seed preference, will restrict their intake to only a portion of the total grain available during reinforcement (Portmann, 1961).

Increased total reinforcement time, then, will only provide the pigeon with more time to eat, but not (necessarily) proportionally more food. Second, it may well be the case that a pigeon, because of physiological limitations, simply cannot eat as efficiently for 4 sec as it can for 2 sec. Doubling reinforcement time does not necessarily mean that a bird is therefore going to eat twice as much. Also, the actual amount of food an animal consumes in 4 sec will probably decrease as a function of satiation which means magnitude of reinforcement will not hold constant throughout an experimental session. Finally, doubling reinforcement time for two birds does not guarantee that both birds will increase their intake in the same proportion, making intersubject comparison difficult at best.

In any case, there is no evidence that an animal's intake is proportionally related to feeding time, making it impossible to conclude that simply increasing duration of reinforcement (access time to a grain hopper) will systematically increase reinforcement magnitude. A more acceptable procedure would be to use water, pellets, shock-off time, or ICS as the reinforcer since their quantity can be easily and exactly controlled. Increasing the magnitude, or amount, of water for example would be a simple matter of opening a valve wider (or longer), as more water was desired. Then by insuring, via intermittent observation, that all the water is consumed at reinforcement, very small and precise increases could be made in the amount of reinforcement delivered that would perfectly correlate with the amount of reinforcement that each

animal consumes.

The final concern of this review deals with the contrast effect first reported by Schuster (1959). Though Schuster reported only transient contrast effects at higher FR values, he nevertheless showed that at lower FR values, pausing before the smaller FR components (held constant at FR 20) significantly decreased as pausing in the longer FR components increased. This is intriguing in that FR short pausing was affected solely as a function of increasing FR size in the alternate components. This further supports the notion that variables other than the size of the immediately up-coming FR, do play a role in controlling pause length, i.e., the context of the schedule in which such changes in FR size are made. Asserting PRP is only determined by the nature of up-coming events, may be as functionally incomplete as were earlier assertions that up-coming FR size was the determinant of pause length. However, a complete analysis of Schuster's data remains difficult for two reasons.

To begin with, Schuster's experimental design is inadequate in that it does not clearly isolate the effects that preceding and/or up-coming conditions have upon the pause after reinforcement; i.e., pauses before the small FR (FR 20) were always preceded by a large FR, and always followed by completing an FR 20. Therefore, the decrease in pausing before FR 20 cannot be specifically attributed to either the size of the preceding or the immediate FR. This leaves unanswered the question of whether pausing in fixed ratio schedules is controlled by preceding or up-coming conditions,

or both.

Two studies allegedly contribute to an understanding of the role that preceding FR size has upon PRP. Mintz, Mourer, and Gofseyeff (1967) used various two-component multiple fixed-ratio schedules and presented pairs of FR components to pigeons; i.e., two small FRs, then two large FRs, etc. In this way, pauses after reinforcement were preceded by either a small or a large FR. The authors felt this technique would effectively isolate the effects that preceding as well as up-coming FR size have upon the length of PRP.

As expected, the authors reported that pausing before the large FR components was significantly longer than before the smaller components. However, Mintz et al. found that there was a significant difference in FR-long pausing depending upon whether the preceding run was a small or a large ratio. If the preceding run was a short FR, PRP before a large FR component was longer than if the preceding ratio was a large one. These results confirm that PRP is primarily affected by the size of the up-coming FR, but the authors also conclude that these data show PRP is affected by the size of the preceding ratio.

However, these data lend themselves to another interpretation. The results reported by Mintz et al. (1967) can be interpreted as follows: pausing before large FR components was 1) longer when the next ratio was to be another large FR, and 2) shorter when the next ratio was to be a small FR. This latter interpretation is tenable largely because subsequent conditions (e.g., the size of the

response requirement that will follow the immediate FR) are potentially discriminable due to their rigid order of presentation; i.e., two large FRs, then two small FRs, etc. It is possible that the results reported by Mintz et al. (1967) are due to the animals discriminating up-coming events and not due to the nature of conditions that have already transpired (e.g., the size of the previous FR). The results from Mintz et al. (1967) then do not necessarily contradict the contention that PRP is controlled by the nature of up-coming events in general, and in fact they may support it.

The second study relevant to this discussion is one reported by Findley (1962), who also examined PRP as a function of ratio size except that instead of a single species and multiple FR schedules, he exposed a rat, a bird, and a monkey to various sizes of mult mix (red light) mix (green light) schedules; i.e., the rat performed under a mult mix FR 25 FR 75 FR 225 mix FR 225 FR 75 FR 25, the bird a mult mix FR 33, FR 132 FR 528 mix FR 528 FR 132 FR 33, and the monkey a mult mix FR 50 FR 200 FR 800 mix FR 800 FR 200 FR 50. Analysis of latency means showed that pauses prior to the larger ratios were proportionally longer than those prior to the smaller ratios, regardless of the order of presentation and regardless of species.

Findley concludes that in this procedure, however, pause length is likely to vary both "... as a function of the ratio size just completed as well as a function of the ratio programmed next" (p.132). But that pause length "... is not determined simply by

the size of the previous ratio" is obvious, since "... the length of pauses is not greatly different whether preceded by the largest ratio or by the middle-sized ratio" (p. 132).

To further delineate the effects that preceding ratio size has on PRP, Findley exposed the same monkey and bird to a similar, but slightly modified schedule. The monkey and bird were exposed to a mult mix FR 33 FR 132 FR 528 mix FR 132 FR 132 FR 132. A close visual examination of the cumulative records reveals that pausing before FR 132 differed depending whether the FR 132 occurred in the presence of the green light (FR 132 FR 132 FR 132) or the red light (FR 33 FR 132 FR 528). In the green light component, pausing before FR 132 was virtually non-existent, whereas in the red component pausing before FR 132 was (at times) of considerable length. The increased length of pausing before FR 132 in the red component may be attributed to 1) the small size of the preceding ratio (FR 33) or 2) to the size of the ratio that always <u>followed</u> completion of the FR 132 (FR 528). More experimentation is needed before these data can be adequately interpreted.

As long as subsequent schedule conditions (those that follow the ones immediately present) remain discriminable, animals may pause relative to the nature of those conditions. Perhaps the only way that the effects of subsequent schedule conditions can be controlled for, would be to make those conditions indiscriminable; i.e., by making them occur in a random order. Randomizing the order that FR components are presented would severely limit their discriminability, and would therefore allow a cleaner analysis of

the effects that preceding FR size has upon PRP. In this way, the only stimuli that animals could pause relative to, would be 1) the size of the ratio just completed, and/or 2) to the size of the ratio immediately up-coming. Until a control for subsequent schedule conditions is implemented, the data from Findley (1962) and Mintz et al. (1967) remain ambiguous.

A second difficulty in analyzing Schuster's (1959) report of contrast is in explaining why on the one hand contrast is only transitory (at high FR values). But, that contrast in this situation can be sustained at lower FR values has been supported by Crossman (1971). In this experiment, two pigeons were exposed to alternating two component multiple fixed ratio fixed ratio schedules similar to those used by Schuster (1959). The short FR component was held constant at FR 10, as the FR long component was changed to FR 15, 20, 25, 30, 35, 40, 50, 55, 45, 35, 25, 15, 10, 15, 20, 25, and finally to FR 30. Results showed that pausing in the large FR components varied relative to changes in size of those components and that pausing in the small FR components was inversely related to FR long pausing. That is, as pausing increased in the large FRs, pausing in the smaller FR components decreased proportionally; i.e., contrast affects. These results are similar to Schuster's (1959) in that the decrease in FR short pausing is in fact present and sustained.

Exactly how demonstrations of sustained contrast modify (if at all) the notion that only up-coming events functionally control pausing is at present unclear. Future examples of contrast in

multiple fixed ratio schedules should help ascertain the exact conditions under which pause length varies as a function of manipulating the size of alternate ratios.

STATEMENT OF THE PROBLEM

The above review generally supports the contention that PRP is primarily controlled by stimuli associated with events programmed to occur in the future. The present study further examines this notion. First, this study replicates previous findings that relate PRP to up-coming ratio size in multiple fixed-ratio schedules. An attempt is also made to isolate the relative control that preceding and up-coming FR size have upon the length of time animals pause after reinforcement by randomizing the order that FR components are presented. Second, this study more clearly delineates the effects that changes in reinforcement magnitude have upon PRP. This is accomplished by precisely adjusting the amount of reinforcement (water) delivered at FR completion, which perfectly correlates with the amount that animals (rabbits) consume during reinforcement. And third, the procedure described below closely examines whether manipulations of FR size and reinforcement magnitude produce contrast effects similar to those reported by Schuster (1959) and Crossman (1971).

A final purpose of this report is to critically evaluate the usefulness of the term "post-reinforcement pause." It is the position of this paper that though "PRP" accurately describes where and when pausing occurs, it fails to sufficiently indicate functional variables associated with it. In fact, PRP may only seduce the reader into assuming that pause length is somehow related to events that have already transpired.

METHOD

Subjects

Two adult New Zealand White male rabbits (WR-1 and WR-2) were maintained on 23 hour water deprivation and trained to paw press with water reinforcement. Both animals had had previous experience with multiple fixed ratio schedules.

Apparatus

A commercial picnic ice chest, 14" x 20" x 16", was converted into an operant chamber by installing a wire mesh floor and an aluminum intelligence panel, 14" x 16" near one end of the chamber. Mounted vertically in the panel was a 2" (diameter) translucent response key centered 3" above the chamber floor. A water-delivery reservoir (4 cc max capacity) located slightly below and to the left of the response key, delivered reinforcement via an adjustable timer. The only light source was the response key that was lighted from the rear by either a red or blue Christmas tree light. The response key was darkened during reinforcement and no house light was available. Ventilation and sound masking were provided by an exhaust fan running continuously.

In an adjoining room a PDP-5 (Digital Equipment Corporation) computer recorded post-reinforcement pause times from which means were calculated after each session. Schedule programming was accomplished by electromechanical apparatus located in the computer room.

Procedure

Each day the animals were carried in a restrainer box from their individual home cages to the apparatus and allowed to earn a maximum of 40 water reinforcers ½ cc each (except as noted below). Then they were returned to their home cages and given an additional 20 ccs of water and food ad lib.

Experiment I

Animals were initially shaped to key press with water reinforcement on CRF. They were then gradually shifted to an FR 10, and finally to an alternating two-component multiple FR 10 FR 10. Individual FR components were associated with either a red light (FR 10) or a blue light (large FR). Once stabilized at mult FR 10 FR 10, WR-1 was shifted in steps of five to a mult FR 10 FR 30 and allowed to stabilize. Similar shifts were then made to mult FR 10 FR 50, mult FR 10 FR 40, mult FR 10 FR 20, and finally back to the original FR 10 FR 10. WR-2, after having stabilized at mult FR 10 FR 10, was shifted to mult FR 10 FR 20, then to mult FR 10 FR 40, mult FR 10 FR 50, mult FR 10 FR 30, and finally back to mult FR 10 FR 10. For both animals, mean latencies were recorded between the onset of the key light after reinforcement and the first response made on the up-coming FR. Stability at each schedule level was determined when the latency means for both large and small FR components showed no systematic trend over three consecutive days.

Once the above series was completed, the following two sets

of variations were conducted in order to demonstrate stimulus control by the colored lights associated with the different FR components. After the animals were restabilized at mult FR 10 FR 30, an animal (WR-1) was tested with the colored lights, previously associated with the FR-long and FR-short components, reversed so that the lights were associated with the opposite FR component; i.e., red light = FR 30, blue light = FR 10. Following this manipulation, stability was recovered under original baseline conditions and PRPs were then re-examined with presentations of the two FR components occurring at random, instead of simply alternating. Randomization was accomplished vis a vis a Lehigh Valley probability generator set at 50:50. The other animal (WR-2) was also tested according to the procedures just described, except that the order of condition changes was opposite of those used for WR-1. That is, the second animal was tested first for order effects (random condition) and second for color reversal.

Experiment II

Experiment II began when the same two rabbits had restabilized at mult FR 10 FR 30. At that time, the magnitude of reinforcement for the FR 30 component was increased to 4 cc, then decreased to 3 cc, 2 cc, 1 cc and finally back to the original ½ cc with stability as defined in Experiment I established at each condition. Reinforcement in the FR 10 component was always ½ cc.

Experiment II employed identical apparatus, and experimental procedures as was used in Experiment I except that the session

length was shortened to 15 reinforcers per day. A shorter session length was implemented to preclude satiation effects that would result from the animals receiving more than 20 cc of water during each experimental session.

RESULTS

Experiment I

Figure 1 shows relative changes in pause relationships for both animals as the size of one FR component was systematically varied. When the two FR components were equal (FR 10 FR 10) pausing prior to both ratios was identical. At mult FR 10 FR 30 a pause differential develops and continues to expand relative to the increases in schedule size, independent of the different order of schedule presentation for the two animals. A nearly linear relation exists between the size of the large FR component and the amount of time each animal paused before beginning that component. PRPs shown in Figure 1 are derived by taking the mean of the final three sessions at each schedule level.

Figure 1 also shows that for WR-1, pausing prior to the FR 10 component slightly increased even though the size of that component was held constant throughout the experiment. However, for WR-2, pausing prior to FR 10 showed no systematic change. See Table 1 for a complete listing of latency shifts that accompanied these schedule changes.

Figures 2 and 3 show representative cumulative records for WR-1 and WR-2 respectively at each of the five schedule levels (records A thru E) with alternating FR components. For WR-2, besides there being a slight increase in overall rate as a function of increasing the size of the large FR component, it can be seen that once stabilized, responding is extremely uniform and shows

little variability. The same is true for WR-1 except that there is little change in response rate as a function of changes in schedule size. Record F in Figures 2 and 3 show response patterns at mult FR 10 FR 30 as FR components were presented at random. With random presentations, relative pause differences between FR 10 and FR 30 remained virtually undisturbed; i.e., for WR-1, pausing at mult FR 10 FR 30 averaged 11.56 sec and 37.02 sec respectively when presented alternately, and 13.614 and 37.536 sec when presented at random. For WR-2 pausing at mult FR 10 FR 30 presented in alternation averaged 24.92 sec and 33.10 sec respectively, and with randomized presentations pausing averaged 22.1 sec at FR 10 and 26.10 sec at FR 30.

Figure 4 shows shifts in the pause differential for WR-2 at mult FR 10 FR 30 under light reversal conditions; i.e., colored lights normally associated with either the small FR or the large FR components were reversed so that the red light correlated with FR 30 and the blue light with FR 10. It was found that relative pause differences between FR 10 and FR 30 were independent of the particular stimulus correlated with the two components; i.e., pausing at FR 10 (red light) averaged 24.62 sec and pausing at FR 30 (blue light) averaged 33.185 sec, whereas pausing at FR 10 (blue light) averaged 21.074 and pausing at FR 30 (red light) averaged 28.194. Data for WR-1 (not shown) are comparable to WR-2's. After initial exposure, animals paused longer before FR 30 than before FR 10 regardless of the colored lights correlated with either ratio size and regardless of the order that FR components were presented.

Experiment II

Figure 5 shows shifts in relative pausing (at mult FR 10 FR 30) as the magnitude of reinforcement delivered at the completion of the FR 30 component was varied from ½ cc, 4 cc, 3 cc, 2 cc, and finally to 1 cc. The order of magnitude manipulations are not reflected in the graph to make visual comparison easier. See Table 2 for a complete listing of changes in pause ratios that occurred as a function of altering reinforcement magnitude.

For both animals, the FR 30 pause decreased as reinforcement magnitude delivered in that component increased. At FR 10 (½ cc) FR 30 (½ cc) pauses were approximately 20 sec longer in the FR 30 component than in the FR 10 component for WR-1, and nearly 18 sec longer for WR-2. As reinforcement magnitude in the FR 30 component was increased to 4 cc, pausing in that component became approximately 18 sec shorter than in the FR 10 component for WR-1 and 22 sec shorter for WR-2. In other words, the pause differential that normally existed at FR 10 FR 30 was almost exactly reversed as a function of increasing the magnitude of reinforcement delivered in the longer component from ½ cc to 4 cc. Moreover, as the reinforcement magnitude was lowered to 3 cc, 2 cc, and 1 cc, relative pausing approximated baseline values. Actual baseline recovery at mult FR 10 (½ cc) FR 30 (½ cc) was only demonstrated for WR-2 since WR-1 died before performance stabilized.

Figure 5 also shows that as WR-1's pause time in the FR 30 component decreased, pausing in the alternate (FR 10) component remained unaffected. The reverse is true for WR-2; i.e., an

increase in FR 10 pausing accompanied the decrease in FR 30 pausing, indicating a contrast effect.

Figure 1. Changes in pausing as one FR component was raised from FR 10 to FR 50. See text for the order of exposure to these conditions.

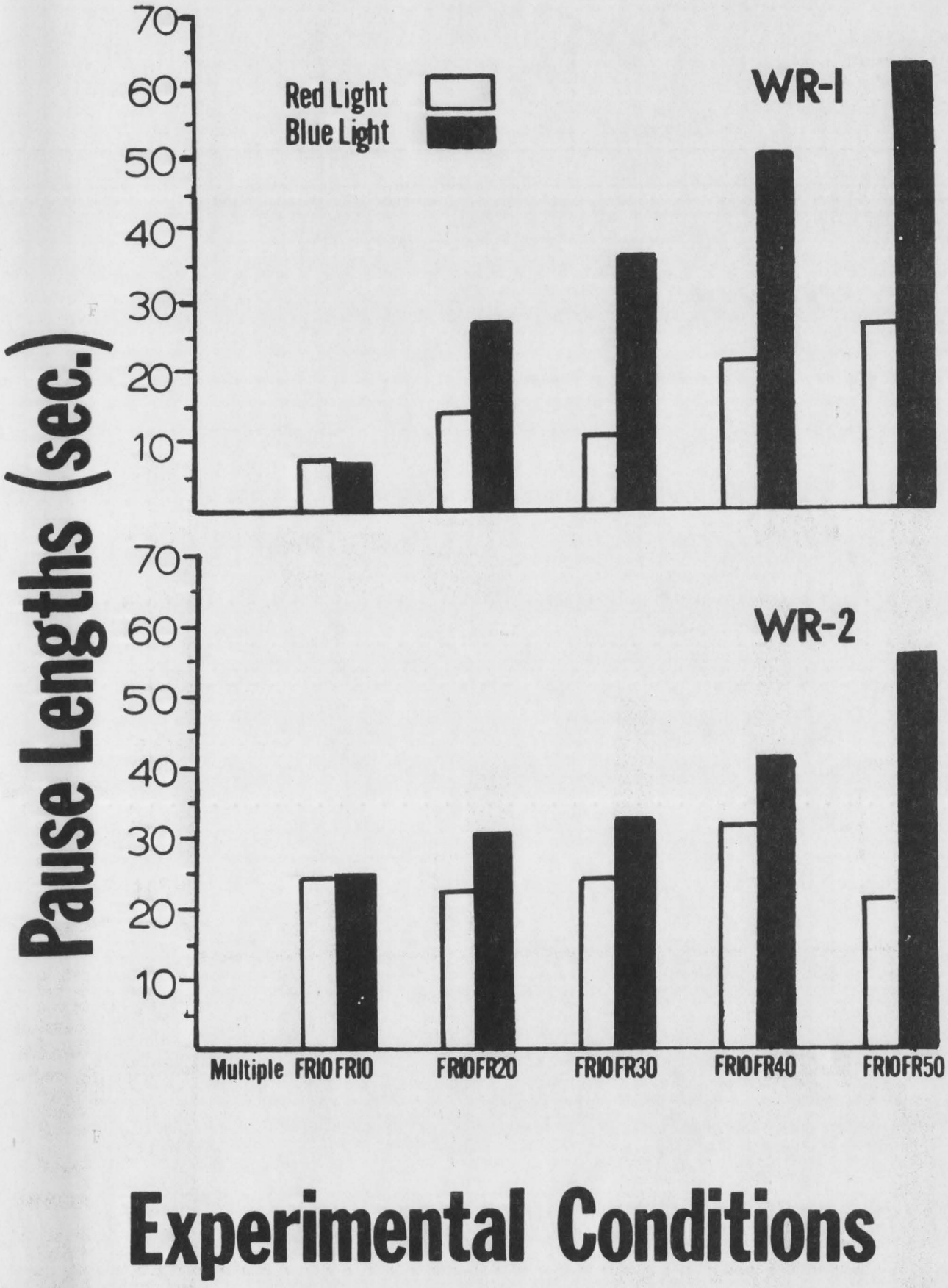
Red Light
Blue Light
WR-1
WR-2
70
60
50
40
30
20
10
Pause Lengths (sec.)
Multiple FR10 FR10
FR10 FR20
FR10 FR30
FR10 FR40
FR10 FR50
Experimental Conditions

Figure 1

Figure 2. Representative cumulative records for WR-1 at each of six schedule conditions. Condition A represents stable responding at mult FR 10 FR 10, B at mult FR 10 FR 20, C at mult FR 10 FR 30, D at mult FR 10 FR 40, and E at mult FR 10 FR 50. Record F shows responding at FR 10 FR 30 with randomized component presentations. The marker record below each cumulative record indicates FR 10 (up) and FR-long (down) components respectively. Pips indicate reinforcement delivery.

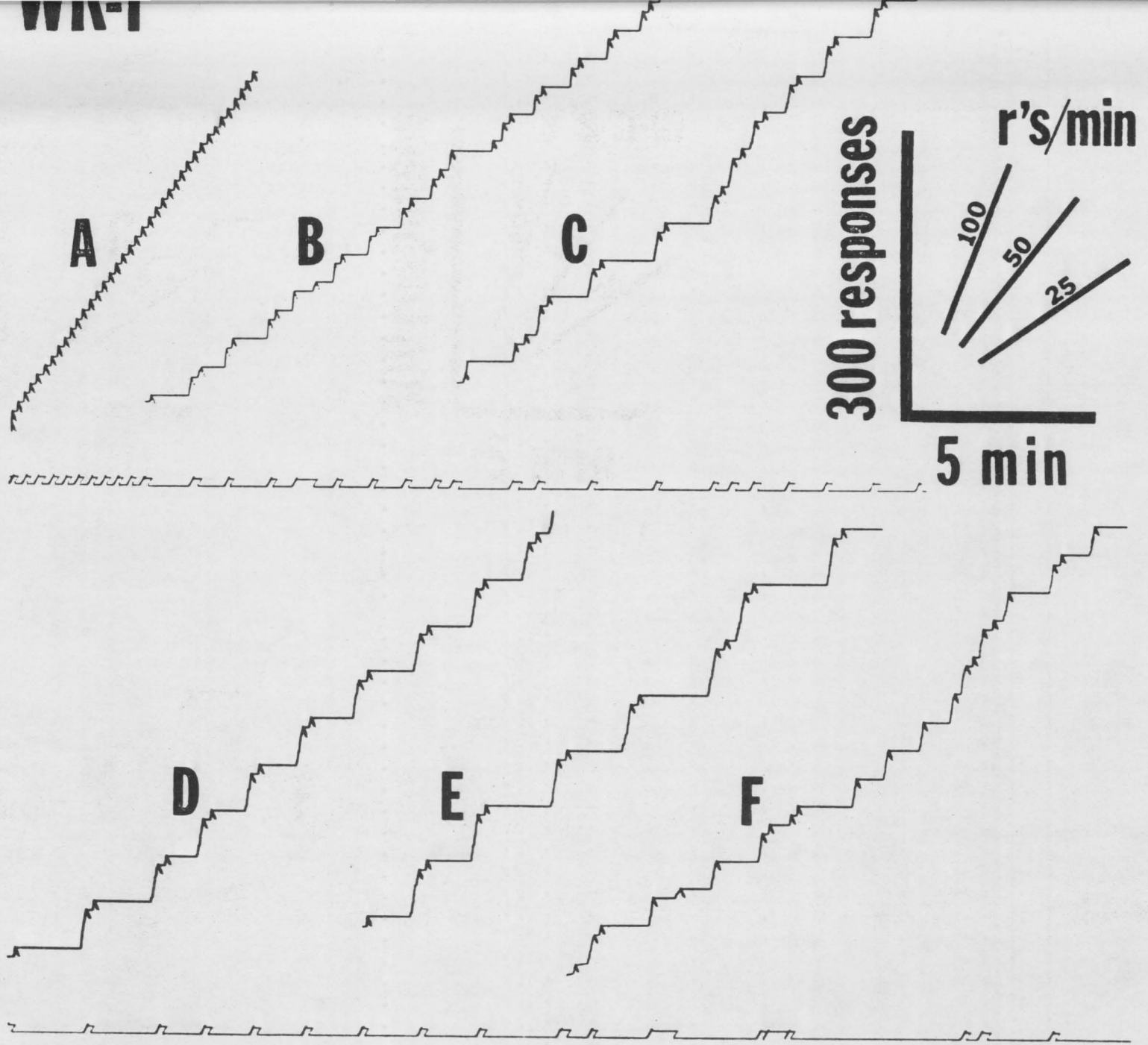

Figure 2

Figure 3. Representative cumulative records for WR-2 at each of six schedule conditions. Condition A represents stable responding at mult FR 10 FR 10, B at mult FR 10 FR 20, C at mult FR 10 FR 30, D at mult FR 10 FR 40, and E at mult FR 10 FR 50. Record F shows responding at FR 10 FR 30 with randomized component presentations. The marker record below each cumulative record indicates FR 10 (up) and FR-long (down) components respectively. Pips indicate reinforcement delivery.

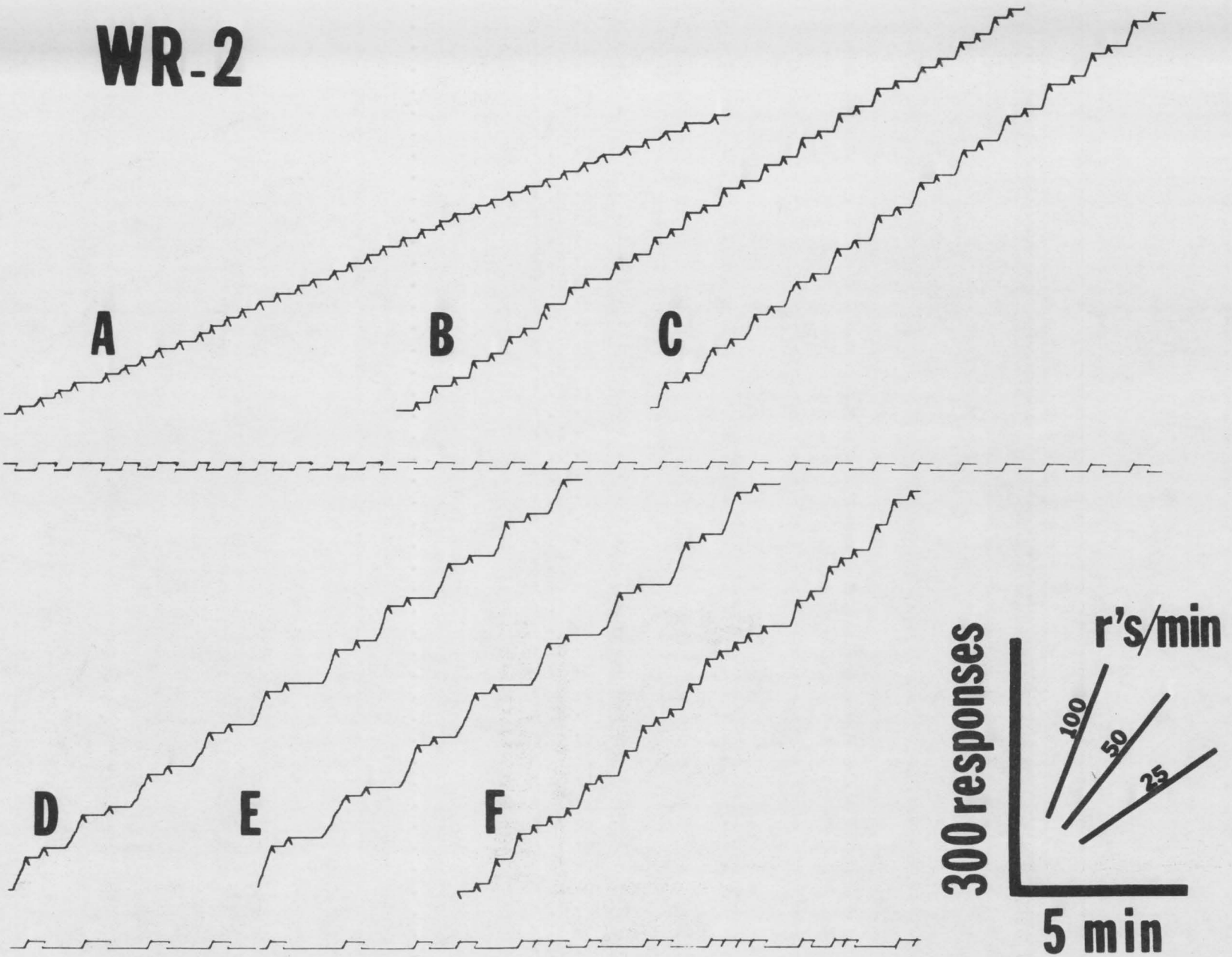

Figure 3

Figure 4. Stimulus control of pause length in FR 10 FR 30 for WR-2. At session 2 the lights correlated with FR size were reversed. Original conditions were reinstated at session 7 and pause distribution immediately reversed.

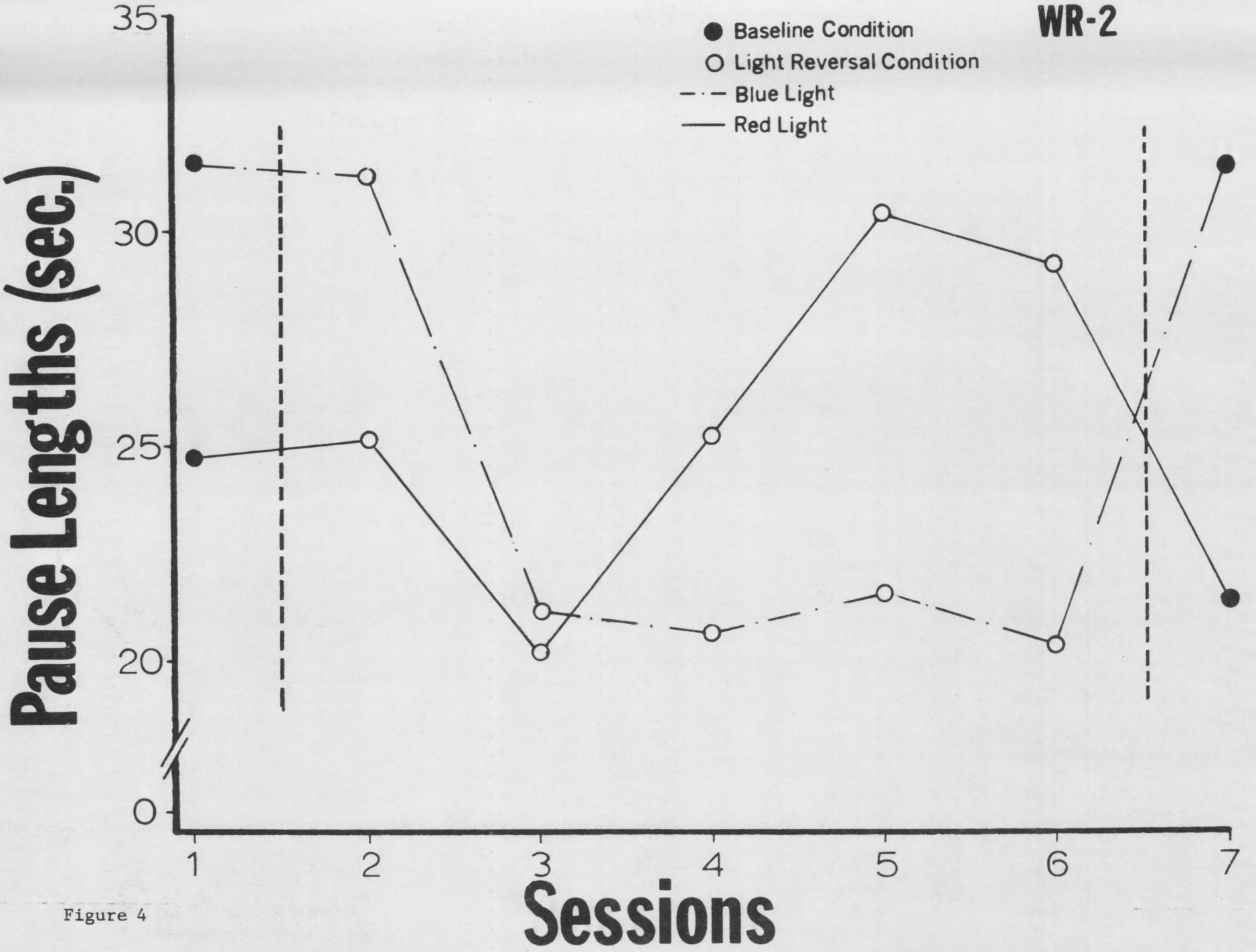
WR-2
Baseline Condition
Light Reversal Condition
Blue Light
Red Light
Pause Lengths (sec.)
35
30
25
20
0
1
2
3
4
5
6
7
Sessions

Figure 4

Table 1. Summary of each subject's performance in Experiment I. See text for the order of exposure to schedule conditions.

EXPERIMENT I

	Sessions	Schedule	Latencies	Standard Deviations
	27	FR 10 : FR 10	8.350 : 8.23	0.03 : 0.01
	34	FR 10 : FR 20	13.51 : 28.2	4.92 : 7.89
WR-1	44	FR 10 : FR 30	11.56 : 37.02	1.46 : 3.59
	6	FR 10 : FR 40	21.98 : 50.22	8.99 : 10.81
	8	FR 10 : FR 50	26.50 : 62.40	4.42 : 3.76
	20	FR 10 : FR 10	24.63 : 25.18	1.58 : 1.03
	15	FR 10 : FR 20	22.94 : 30.70	2.04 : 5.23
WR-2	35	FR 10 : FR 30	22.92 : 33.10	2.95 : 2.50
	7	FR 10 : FR 40	29.63 : 41.60	3.51 : 6.49
	7	FR 10 : FR 50	20.50 : 55.90	7.28 : 2.37

Table 1

Figure 5. Changes in pausing for WR-1 and WR-2 as the magnitude of reinforcement delivered at the completion of the large FR component was increased from ½ cc to 4 cc.

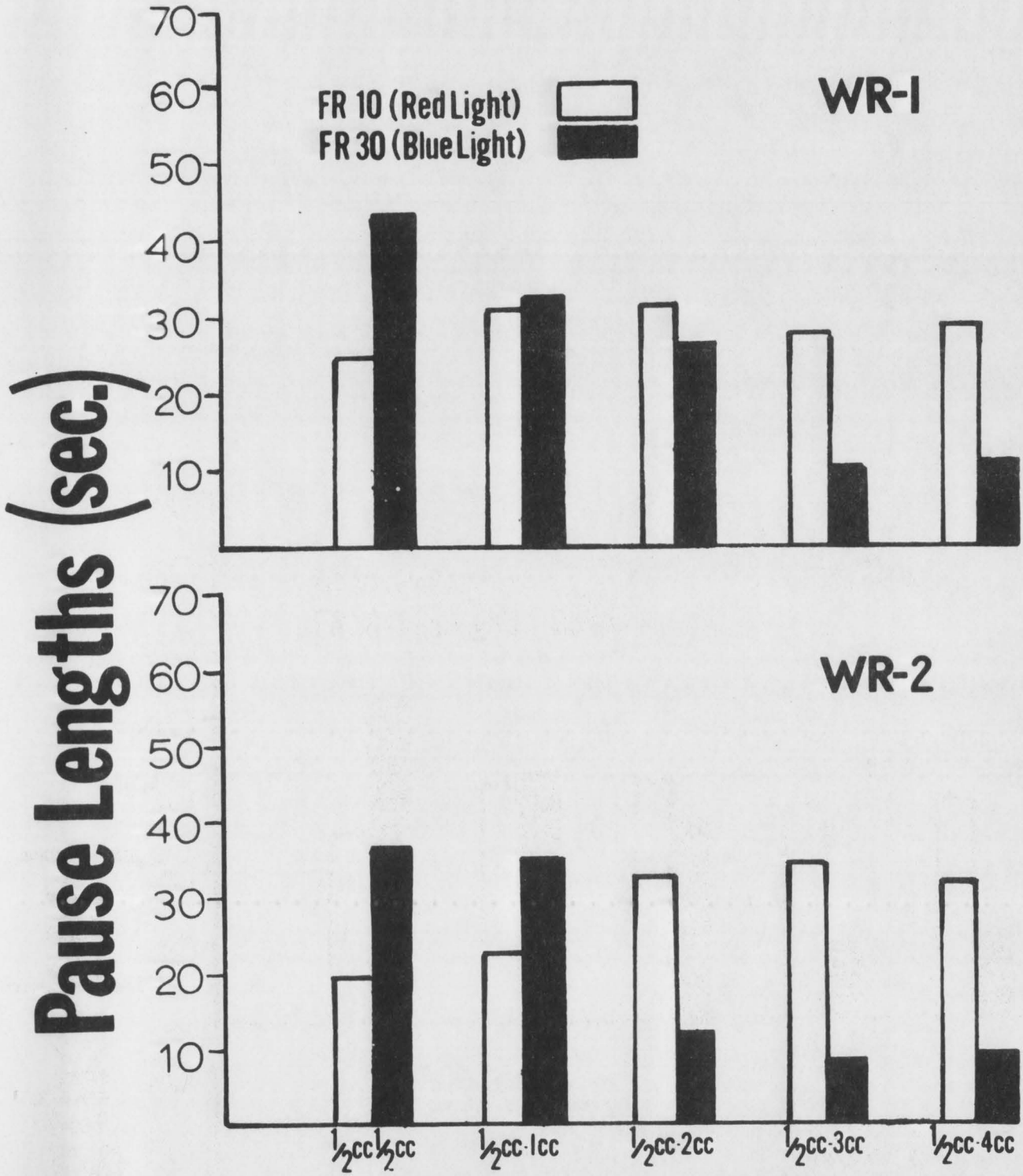
FR 10 (Red Light)
FR 30 (Blue Light)
WR-1
WR-2
Pause Lengths (sec.)
70
60
50
40
30
20
10
½cc-½cc
½cc-1cc
½cc-2cc
½cc-3cc
½cc-4cc
Reinforcement Magnitude Ratios

Figure 5

Table 2. Summary of each subject's performance in Experiment II. See text for the order that subjects were exposed to schedule conditions. Both animals performed on a mult FR 10 FR 30 throughout Experiment II.

EXPERIMENT II

	Sessions	Schedule	Latencies	Standard Deviations
	13	½cc : ½cc	24.89 : 44.21	2.01 : 3.21
	17	½cc : 1cc	31.28 : 32.53	3.11 : 2.09
WR-1	8	½cc : 2cc	33.38 : 26.01	4.13 : 5.61
	11	½cc : 3cc	28.78 : 10.29	2.03 : 3.91
	7	½cc : 4cc	29.11 : 11.51	1.42 : 0.80
	16	½cc : ½cc	19.95 : 37.33	1.77 : 2.19
	12	½cc : 1cc	22.69 : 34.68	2.63 : 4.81
WR-2	9	½cc : 2cc	31.97 : 11.13	2.74 : 1.67
	10	½cc : 3cc	34.40 : 7.93	1.69 : 2.68
	6	½cc : 4cc	31.33 : 9.49	4.88 : 0.94

Table 2

DISCUSSION

This study has shown with rabbits and water reinforcement that "pause after reinforcement" (Ferster and Skinner, 1957) can be controlled by manipulating either fixed ratio size or magnitude of reinforcement. Experiment I demonstrated that increasing the size of an up-coming FR resulted in proportional increases in the time the animals paused before beginning that FR, regardless of the order that the animals were exposed to the various schedules. This finding is consistent with earlier studies that have employed other species and schedules (Kaplan, 1956; Schuster, 1959; Findley, 1962; Felton and Lyon, 1966; Powell, 1968; Crossman, 1968, 1971). In addition, the results from the present study (Experiment I) do not indicate that post-reinforcement pause is affected by the size of the preceding ratio, as suggested by Findley (1962) and Mintz, Mourer, and Gofseyeff (1967). Two different aspects of these results support this conclusion.

First of all, when the FR components were presented at random, the size of preceding FRs varied; i.e., pauses before FR 30 were preceded either by FR 10 or FR 30, and likewise, pauses before FR 10 were preceded by FR 10 or FR 30. A close visual examination of record F in Figures 2 and 3 reveals that pausing before FR 10 was virtually unaffected by the size of the preceding ratio. The same is true of pausing before FR 30. Of course, considerably more experimentation is needed before it can be stated, unequivocally, that preceding FR size does not have an effect on PRP.

Future experimentation should continue to investigate PRPs in mult FR schedules using various ratio sizes. The FR components should be presented in a rigid series and at random so as to more accurately assess what role subsequent FR size has upon the pause after reinforcement. Comparing these two methods of component presentation will provide valuable information regarding the contention that stimuli correlated with up-coming schedule conditions primarily control PRP.

Secondly, in Experiment I pausing before FR did not decrease as a function of increasing the size of the alternate ratio, this also suggests that pausing before FR 10 is independent of the size of the preceding or alternate ratio. This is in direct conflict with reports from Schuster (1959) and Crossman (1971). In fact, in Experiment I the only change in FR 10 pausing was an increase which corresponded to the increases in pausing before the large components (see WR-1, Figure 1). Why there is no evidence of contrast in Experiment I remains unexplained. However, the fact that these animals performed over 12 months in these experiments, and demonstrated surprisingly stable performance at each schedule level (see Figures 2 and 3), suggests to this author that the lack of contrast effects should be an objective of further experimentation. Future studies should attempt to clarify the reasons for the failure of this experiment to produce a decrease in FR 10 pausing.

Experiment II showed that increasing the amount of reinforcement delivered and actually taken by the subjects, in FR 30

components, proportionally reduced the time that the animals paused before beginning those components. The average time that WR-1 paused before FR 10 components did not shift as a function of changing reinforcement magnitude in the FR 30 components. The slight increase in FR 10 pausing for WR-2 conflicts with data from WR-1. The reasons for the apparent contrast effects for WR-2 and yet not for WR-1 remain obscure. But clearly, this study has not determined that WR-2's increase in FR-short pausing was due to the size of the previous reinforcer. The longer pause may have resulted from the relative difference in reinforcement densities associated with large and small FR components. This remains to be investigated. But, in any case, it cannot be concluded from these data that preceding schedule conditions (including the size of the previous reinforcer) are functional in controlling the pause after reinforcement.

Taken together, the results from Experiments I and II support the aforementioned contention that pause time varies primarily as a function of encountering stimuli that are correlated with conditions about to be encountered. Moreover, it should be realized that up-coming FR-size and reinforcement magnitude are only two of many variables that can control the length of post-reinforcement pause. In fact, manipulating any variable that differentially affects the nature of up-coming events will probably be functional in controlling PRP; i.e., response cost (Weiner, 1964), response contingent shock (Azrin, 1959), delay of reinforcement (Azzi, Fix, Keller, and Silva, 1964), inter-reinforcement

interval (IRI) (Neuringer and Schneider, 1968), etc.

However, there may be variables other than the ones contained exclusively in up-coming schedule conditions that affect the degree of control that FR size, reinforcement magnitude, etc. exert over PRP; e.g., satiation (Sidman and Stebbins, 1954), the relative sizes of other ratios in the schedule (Schuster, 1959; Findley, 1962; Crossman, 1971), and perhaps relative reinforcement density associated with each FR. Future research will hopefully investigate these and other variables in an effort to completely delineate the interrelations among factors that control pausing after reinforcement.

The last issue this paper deals with is concerned with the usefulness of the term "post-reinforcement pause." A reader not thoroughly familiar with current research on PRP, might find that the term "post-reinforcement pause" carries with it subtle implications of functionality. Reading, for example, that Felton and Lyon (1966) found post-reinforcement pause length increased with increases in FR size might easily be interpreted to mean that pause length increased because of changes in the size of the previous ratio, or perhaps because of a kind of response-produced suppression which arose from having just completed the previous ratio, i.e., fatigue. This is especially true in view of the fact that PRP has been written about in exactly this manner.

Skinner (1938), for example, has written that "the preceding run ... at a fixed ratio ... acts to produce a pause of some length" (p. 297). "It is obvious that the state of strain ... will be

greater the higher the ratio, and therefore ... proportionally greater average [pausing would be expected to occur] after ingestion" of the reinforcer (p. 298). Skinner obviously felt PRP resulted from an increasing "state of exhaustion" (p. 297), which accrued as responding proceeded on the previous FR requirement. Thereafter, the label "post-reinforcement pause" was coined (Cumming and Schoenfeld, 1961; Clark, 1962) since it accurately described the phenomenon with parsimony and clarity. The term PRP was quickly accepted and widely used as a description of, rather than an explanation for, pausing on fixed ratio schedules. However, descriptions of clarity and parsimony are scientifically useful only insofar as they remain functionally accurate and appropriately used (see Skinner, 1962, p. 224).

Other investigators have also pointed out that "post-reinforcement pause" is misleading as a term describing the pause after reinforcement, since it implies that the "pause" is somehow connected to the last reinforcer (Griffith and Thompson, 1972). Consequently, terms such as "pause before ratio run," "between-ratio pause" (Griffith and Thompson, 1972), "pre-ratio pause," and "post-FR pause" (Crossman, 1971) have been suggested as substitutes since they avoid the improper implication that pausing is functionally related to events already transpired.

Although the above alternatives are all tenable, the term originally used by Ferster and Skinner (1957, p. 89) is equally viable; i.e., "pause after reinforcement." This term is particularly useful for two reasons. To begin with, it makes a clear

distinction between reinforcement and pausing which fosters the notion that the two events are mutually independent. This should provide the novice reader with a better basis from which he can operationally understand the phenomenon. The second advantage for using "pause after reinforcement," is that it applies equally well to interval schedules. Pausing after reinforcement is typical of animals performing on interval schedules too, so it would behoove the scientific community to adopt a term that is equally well suited for both types of schedules (ratio and interval), and which describes the event accurately and parsimoniously. For these reasons the term "pause after reinforcement" or PAR, may be considered as the most useful description of the pause that follows reinforcement delivery.

In conclusion, this paper has pointed out that the pause after reinforcement appears to vary as a function of encountering stimuli that correlate with the nature of up-coming events. However, it should be realized that these same stimuli are also correlated with events that have already transpired. Future research should attempt to investigate PAR in light of the stimulus control that might exist as a function of pairing a discriminative stimulus with past and with future events. It is possible that a stimulus may control pausing 1) insofar as that stimulus sets the occasion for future events, and/or 2) in that the stimulus is correlated with a previous reinforcer. To date there is little evidence that the latter kind of stimulus control exists. Subsequent investigations will need to investigate PAR in conditions where discriminative

stimuli are, and are not systematically correlated with past events. If pairing a discriminative stimulus with past events is non-functional in controlling PAR, there should be no difference between these two experimental conditions.

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